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ANTIBIOTICS AND POTATO RING ROT IN ALASKA[1]

CHARLES E. LOGSDON[2]

INTRODUCTION

Potato ring rot caused by *Corynebacterium sepedonicum* (Spiek. & Kott.) Skapt. & Burkh. has been a serious problem for Alaska potato growers since some time prior to 1948. The exact date of its introduction is uncertain, but Lefebvre (8) reports that by 1948 it had reached epidemic proportions in the Tanana Valley and was present in the Mutanuska Valley and Anchorage areas.

Seed certification and strict grade enforcement of table stock potatoes combined have partially controlled ring rot in Alaska, but these measures have not eliminated the disease. Both of these methods depend on detection of the disease and elimination of infected lots. Unfortunately, the disease is not always detectable under Alaskan environmental conditions. A better solution to the ring rot problem appears to be a seed treatment with chemotherapeutants which are translocated within the plant to the site of infection and kill the bacteria. Some antibiotics are known to be translocated within plants and are often effective against bacteria at extremely small concentrations.

The use of antibiotics for general plant disease control has been summarized by Anderson and Gottlieb (1), by Leben and Keitt (7), and by Zaumeyer (13). Among the hundreds of antibiotics tested, only a relatively few have promised control of potato diseases. Valeria Van Schaak (12) attempted to control potato ring rot by seed treatment with penicillin with apparently very favorable results. Bonde (3) found streptomycin highly effective in the control of bacterial rot of potato seed pieces. His work (4) showed a very good control of black leg on a field basis when Agri-mycin 100, a product containing both streptomycin and Terramycin, was used. MacLachlan and Sutton (10) reported excellent control of potato ring rot with Terramycin, good control with Agri-mycin 100, and some control with Agristrep, erythromycin, penicillin G, and Phytomycin. Part of the effectiveness of Terramycin was attributed to its ability to be translocated both upward and downward in the plant. Bonde and Johnson (5) report that streptomycin sulfate was the most effective antibiotic included in their preliminary studies on control of potato ring rot. Some control was also obtained with aureomycin and Terramycin. In later tests, Actidione and Phytomycin were found most effective for ring rot control either alone or in combination with streptomycin sulfate. Bacitracin was one of several antibiotics which they found to be ineffective in controlling ring rot.

MATERIALS AND METHODS

The experiments here reported are confined to the variety, Green Mountain. Inoculations were made by cutting seed pieces into a water

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[2]Plant Pathologist, University of Alaska, Agricultural Experiment Station, Palmer, Alaska. The author is indebted to Chas. Pfizer & Co. and S. B. Penick Co. for supplying the antibiotics used in these experiments.

suspension of ooze from tubers infected by *Corynebacterium sepedonicum*. Seed treatment materials were dissolved or suspended in water and the seed treated by momentarily dipping it into this material. Inoculated and treated seed pieces were handled in waxed kraft paper bags to avoid mixtures and/or contamination.

Notes were taken at harvest to ascertain those tubers showing external symptoms of ring rot. Apparently healthy tubers were stored 4-5 months and then examined for internal symptoms by slicing across the stem end. Data are reported as percentages of infected hills or infected tubers. For statistical analysis, percentages were converted to degrees.

Results

Treatment of inoculated seed pieces in 1955 with Agri-mycin 100 at 0, 100, 500, and 1000 ppm (based on streptomycin content) decreased the percentage of infected hills in direct relation with increase in concentration (Table 1).

It could be presumed that since increased control and increased concentration had a straight line relation, higher concentrations might give even better control. Also, since the work of Gray (6) showed that the addition of 1% glycerol improves the absorption of streptomycin, an experiment was conducted in 1956 in which inoculated cut seed was treated with Agri-mycin 100 with and without 1% glycerol. The concentrations of streptomycin in these treatments were 100, 500, 1000, and 5000 ppm.

The addition of glycerol did not increase the effectiveness of Agri-mycin 100 in controlling ring rot (Table 1). Agri-mycin 100 gave what might be termed effective control where the concentration of streptomycin in the Agri-mycin was 5000 ppm; however, this concentration is so costly that it is not economical as a seed treatment. Moreover it had a detrimental effect on potato yields as will be discussed in a later section.

Agri-mycin 100 not only contains 15% streptomycin but also contains 1.5% Terramycin. Some workers, notably MacLachlan and Sutton (10), have concluded that Terramycin is more effective in ring rot control than streptomycin. An experiment was made in 1956 to test the effectiveness of Terramycin at concentrations of 100, 200, 300, 400, and 500 ppm.

Although control obtained with Terramycin was statistically significant (Table 1), it was not nearly as great as that obtained by levels of Agri-mycin 100 which contained the same concentrations of Terramycin. This indicates that either streptomycin is the effective portion of Agri-mycin 100 or that there is a synergistic effect between streptomycin and Terramycin in the control of ring rot.

Since workers at the Pfizer Company had indicated that the effectiveness of Terramycin and of Agri-mycin 100 might be increased by acidifying the treating solutions, these two materials were tested in 1957 at pH 4, 5, 6, 7, and 8. Terramycin was used at the rate of 100 ppm and Agri-mycin 100 was used at the rate of 500 ppm streptomycin. The concentration of Terramycin in the Agri-mycin 100 at this rate was 50 ppm. The solutions were not buffered to maintain pH but were adjusted with HCl or NaOH prior to treatment.

Results with Terramycin did not differ from those with the water

TABLE 1.—*Percentage of infected hills from seed inoculation with Corynebacterium sepedonicum and subsequently treated with various antibiotics.*

Expt.	Antibiotic	Concentration (ppm)	Percentage of hills infected*	
			Without Glycerol	With 1% Glycerol
1.	Agri-mycin 100	0	86.5	
		100	82.7	
		500	65.5	
		1000	44.7	
2.	Agri-mycin 100	0	62.4	56.3
		100	40.0	67.0
		500	18.8	29.5
		1000	16.0	13.3
		5000	6.0	7.3
3.	Terramycin	0	62.4	
		100	67.3	
		200	63.1	
		300	58.0	
		400	45.0	
		500	34.4	

*Tubers examined at harvest and again after storage for 4-5 months.

check. Statistically, pH of the solution had no effect on the effectiveness of the Terramycin or Agri-mycin 100. Although Agri-mycin 100 reduced infection, none of the treatments gave economical control.

In the course of these investigations, two other antibiotics were evaluated for ring rot control. These were amimycin (1, 10, and 100 ppm) and bacitracin (100 ppm, 500 ppm, and at intervals of 1,000 ppm from 1,000 to 10,000). Neither material reduced infection.

Experiments in 1955 indicated that treatment of inoculated seed pieces with bacitracin stimulated the development of the disease. Although the total percentage of infected hills in the treated plots was not significantly different from that in the check, a greater proportion of the infected hills was evident at harvest time. Where bacitracin was used at the rate of 100 ppm without glycerol, 48% had external symptoms at harvest; at 500 ppm, 56%; at 1,000 ppm, 64% and at 5,000 ppm, 70% had external symptoms at harvest time. When 1% glycerol was added to the same concentrations of bacitracin 44%, 50%, 54% and 66% respectively, had external symptoms at harvest. A similar response to bacitracin treatment was noted in 1956. In two other tests, no relationship was demonstrated between ring rot incidence and bacitracin treatment. It is suggested that if bacitracin does tend to increase disease development—as two of four experiments indicate—the effect is most likely one of suppressing organisms that are otherwise antagonistic to ring rot bacteria.

Phytotoxic effects have been reported for some antibiotics. Anderson and Nienow (2) found that concentrations of streptomycin beyond 50 units per ml were toxic to tomato and radish seedlings. They also found that soybean lateral roots were stunted when seedling roots were immersed

in streptomycin solutions. Bonde (4) reports that seed treatment of potatoes with 50 ppm of streptomycin nitrate stimulated the plants, but that slight retarding of growth occurred when 100 ppm were used. Bonde and Johnson (5) found that Actidione caused a 5 to 10% reduction in emergence of potatoes. Uninoculated potatoes in Alaska showed some phytotoxic effects with Agri-mycin 100 treatment as reflected in yield. The most severe reductions in yield (50%) were shown at a concentration of 5,000 ppm. Much of the yield reduction can be accounted for by the reduction in stand, but there was also a delay in the development of those plants that emerged. Where the untreated check produced 63% U. S. No. 1 size tubers, only 39% U. S. No. 1 tubers were produced by those plants treated with Agri-mycin 100 at 5,000 ppm. Treatment with Agri-mycin 100 at 1,000 ppm also reduced yields significantly, but there was only a slight reduction in the percentage of U. S. No. 1 tubers.

Discussion and Conclusions

It seems obvious that none of the antibiotics tested thus far as seed treatments has practical value for ring rot control in Alaska. A certain amount of control has been obtained, and in some cases very significant reductions in the disease occurred. If control of ring rot with antibiotics is to become economically feasible, however, more information is needed on the mode of action on the disease complex.

The hypothesis on which these experiments were based was that the antibiotics would be absorbed by the plant, translocated to the infected tissue, and act directly on the bacteria. Evidence accumulated from these studies neither confirms nor invalidates this hypothesis. It does suggest, however, that there may be other means by which the amount of ring rot was reduced when antibiotics were used as seed treatments. One possibility is that antibiotics controlling ring rot merely acted as surface disinfestants and thereby reduced the concentration of bacteria available to cause disease. This hypothesis is supported in part by the fact that increased concentrations of Agri-mycin 100 reduced the percentage of ring rot infection detected at harvest; this seems to confirm the conclusions of Starr (11), who showed that reduced ring rot inoculum resulted in a delay of symptoms.

Another possibility is that the primary effect of antibiotics is an adverse effect on the plant itself and only an indirect effect on the bacteria. Logsdon (9) has shown that faster emergence, earlier blooming and more rapid maturity induced by greensprouting is positively correlated with the development of ring rot symptoms in both foliage and tubers. Conversely, where growth of the plant is delayed or slowed—as appears to be the case with high concentrations of Agri-mycin 100—ring rot symptoms are slower to develop.

Probably all three of these factors influence the effectiveness of ring rot control by antibiotics.

Summary

Agri-mycin 100, Terramycin, amimycin, and bacitracin at various concentrations, and in some cases with 1% glycerol added, were tested for their effectiveness in controlling potato ring rot. Ring rot was reduced

with both Agri-mycin 100 and Terramycin. Effective control was obtained only with Agri-mycin 100 at uneconomically high rates. At these rates, phytotoxicity was evident. Amimycin was completely ineffective. There was some evidence that bacitracin might increase infection although this was thought to be an indirect effect. The pH of the treating solution did not appear to alter the effectiveness of Agri-mycin 100 or Terramycin.

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EARLY SCAB RESISTANT DERIVATIVES OF *SOLANUM CHACOENSE* X *SOLANUM PHUREJA*[1]

LEO A. DIONNE AND C. H. LAWRENCE[2]

Potato varieties resistant to the common scab disease caused by *Streptomyces scabies* (Thaxt.) Waksman and Henrici, have been derived largely from the German varieties Richter's Jubel, Hindenburg or their derivatives and to a lesser extent from certain American varieties. Scab resistance has been relatively easy to obtain from the German material but most of the highly resistant derivatives have been late maturing.

A search for additional sources of resistance appears to be warranted. Breeding material that is both early and scab resistant could be of considerable value to the breeders of commercial potatoes.

Several *Solanum* species in the series *Commersoniana* have been reported to be immune to common scab (2). However, these species are diploids or highly sterile triploids. Moreover, they are late maturing, stoloniferous, and tuberize only under short day conditions.

It is theoretically possible to circumvent the problem of ploidy by the use of autotetraploids of the resistant species. Autotetraploids of *Solanum chacoense* are readily crossable with *S. tuberosum* (1). We have found that the F_1 hybrids of such crosses are highly fertile. However, the level of scab resistance in 4n *S. chacoense* x *S. tuberosum* was low, indicating that some factors for scab resistance in *S. chacoense* are incompletely dominant. Also, the hybrids produced numerous long stolons and all were very late maturing.

As an alternative to crossing autotetraploids directly with *S. tuberosum*, we have attempted to incorporate scab resistance into an early diploid non-resistant species, *S. phureja*. The advantages of doing all preliminary work at the diploid level are: (1) the theoretically smaller populations required to obtain recombinations of the desired characteristics, (2) the comparative simplicity of determining the number of genetic factors involved in resistance, and (3) homozygous segregates are easier to obtain.

MATERIALS AND METHODS

The plants to be tested for scab resistance in the greenhouse were grown in the following manner. Tubers were planted in a 1:1:1 mixture of coarse vermiculite, sand, and soil from a field heavily infested with *S. scabies*. The mixture was moistened with an aqueous slurry obtained by grinding scabby Green Mountain potato peelings in a blendor. The F_1 and F_2 hybrids tuberized poorly under normal treatment in the greenhouse. Satisfactory tuberization was induced by grafting scions of Epicure or of U.S.D.A. seedling 41956 into the sprouts of the hybrids when they were from 3 to 4 inches high. All leaves of the stock plants were removed as soon as the scions started growth and all subsequent growth was

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[2]Potato Breeding Section. Acknowledgment is gratefully made to Dr. J. W. McAllan of the station staff, who made the chemical analyses for solanine content.

removed from the stocks as it appeared. Most seedlings responded to grafting by tuberizing at the same time as the Green Mountain plants that were used as controls.

A scab resistant clone of *S. chacoense* was crossed with *S. phureja*. The F_1 hybrids were tested for scab resistance in the greenhouse and the most resistant F_1 plants were intercrossed to produce an F_2 population. The F_2 population was also tested in the greenhouse as outlined above.

A resistant F_2 segregate was backcrossed to *S. phureja* and the seeds were planted in the greenhouse. The resultant plants were transplanted into two inch pots, hardened out of doors for about two weeks and transplanted to a field heavily infested with the scab organism. Each row of seedlings was grown between rows of Green Mountain controls. Selected, resistant BC_1 plants were intercrossed to produce an advanced population that was treated in the same manner as were the BC_1 progeny.

The seedlings were transplanted to the field during the first week of June and harvested at the end of August at which time notes were made on the extent of scab infection, earliness, tuber color and type.

Results

The F_1 hybrids of *S. chacoense* x *S. phureja* varied from moderately to highly resistant but none was as resistant as *S. chacoense*. All were late maturing and stoloniferous. The F_2 population was more variable than the F_1. In a population of about 100 plants, one (Selection #10) was found to be apparently immune to scab, many were highly resistant and others showed various degrees of resistance while several were as susceptible as the Green Mountain controls. Most of the seedlings were very late maturing. Cuttings of the apparently immune selection were transplanted to the field but the plants failed to tuberize before being killed by frost in mid October. Subsequent attempts to infect this selection by the greenhouse method were unsuccessful.

Nearly all the progeny from F_2 selection #10 x *S. phureja* were resistant to scab and many were very early maturing. Several had tuberized and started to mature in two and one-half months after planting in the field. From about 300 plants, twenty early, highly resistant selections were made. Although the tubers of these selections were small, they were typical of good clones of *S. phureja* grown under the same conditions (Fig. 1). Moreover, several had the intense red color of certain strains of *S. phureja*.

About two hundred intercrosses of the BC_1 selections were grown in 1959. These showed the same range of variability as the parental population. Although a few seedlings were susceptible to scab none was as susceptible as the Green Mountain controls. Because susceptibility to scab in this population was expressed as a continuum of types from moderately resistant to highly resistant, it is difficult to draw any conclusions as to the genetic mechanism of scab resistance. However, resistance is not inherited in a simple manner and a number of factors are apparently involved.

Unfortunately, all the scab resistant selections were found to be bitter. Chemical analysis of these revealed a high concentration of solanine in the tubers. The alkaloid content varied from 0.40 mg per gm to 2.0

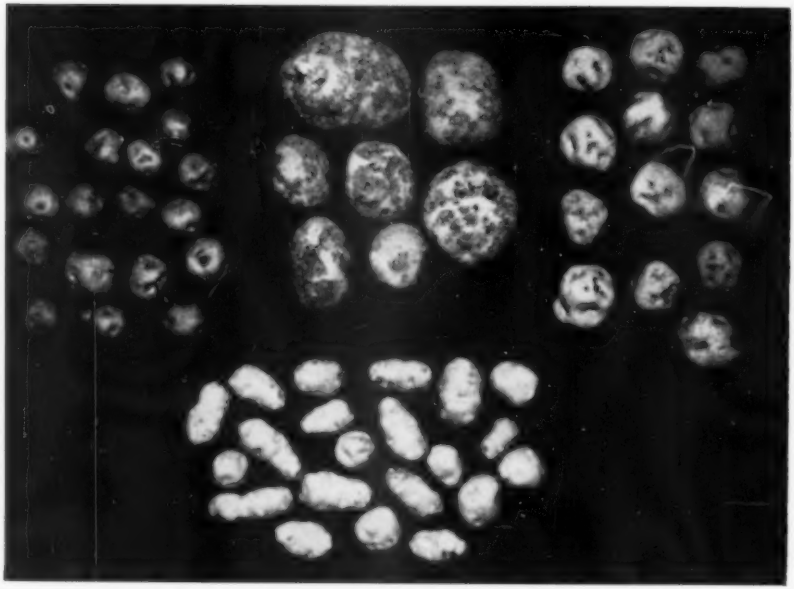

FIG. 1.—Potatoes grown on soil heavily infected with common scab. The large central group is from a hill of the susceptible variety Green Mountain. The three other groups are near-immune, extremely early derivatives of *Solanum chacoense* x *Solanum phureja*.

mg per gm, with an average for all selections of 1.07 mg per gm. Tubers of the *S. tuberosum* variety Katahdin tested at the same time ranged from 0.20 mg per gm to 0.024 mg per gm, with an average for all tubers of 0.22 mg per gm.

Tetraploids of this material have now been obtained by colchicine treatment. These are being evaluated for scab resistance as a preliminary step to crossing them with *S. tuberosum* varieties, to determine the usefulness of this source of scab resistance in the breeding of commercial varieties.

SUMMARY

Early scab resistant diploid derivatives of *S. chacoense* have been obtained from crosses of that species with *S. phureja*. Although high in solanine content the selections otherwise resembled early forms of *S. phureja*. The inheritance of resistance is apparently complex. Tetraploid clones were produced by colchicine treatment, as a preliminary step to transferring this source of resistance to *S. tuberosum*.

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FACTORS AFFECTING THE SULFUR DIOXIDE UPTAKE IN SULFITED PRE-PEELED POTATOES[1]

L. R. Ross and R. H. Treadway[2]

A number of papers have been published concerning the pre-peeled potato industry, and most of these articles are cited in a recent paper (1). These publications deal with various aspects connected with the processing, packaging, and storage of pre-peeled potatoes. Only limited information has been available on the subject of how such factors as concentration, temperature, and composition of the sulfite dipping solution and time of immersion affect the amount of sulfur dioxide (SO_2) absorbed[3] by peeled potatoes. This dearth of information is largely due to the fact that accepted procedures for determining the SO_2 content of peeled potatoes are rather difficult and laborious to execute. A rapid method for the SO_2 determination was recently presented in this Journal (1). Availability of such a simple procedure has enabled us to appraise the important factors influencing SO_2 uptake.

Materials and Methods

All data on the SO_2 content of peeled potatoes presented in this paper were obtained using the shorter method, designated as the "regular" procedure in the reference cited. The sample of sulfited potato was homogenized in a buffer solution at pH 4.4 to extract the sulfite and other soluble constituents. An aliquot of the filtered extract was then titrated with iodine solution, using starch indicator. The sulfur dioxide content was computed as parts per million of potato. Values for SO_2 content found in one set of experiments may not be strictly comparable with those from another set. However, in any given set of experiments, the SO_2 determinations were made on the same day and all precautions were taken to maintain uniform conditions.

U.S.P. grade sodium bisulfite ($NaHSO_3$) and A.C.S. grade citric acid monohydrate were used as reagents in the dipping bath. Potatoes of a single variety and grown in one area (Long Island Katahdins) were used in order to make the results as comparable as possible. Except for one set of experiments, the raw material was all from the same lot of 1958 crop. Experiments on the temperature effect were made on the 1959 crop.

Whole, peeled potatoes of nearly spherical shape were used in the sulfiting experiments except in a few instances where it will be noted that French-fry slices were employed. Use of peeled potatoes of the same shape, size, and surface area is important when results of SO_2 absorption are to be compared.

[1]Accepted for publication August 19, 1960.

[2]Eastern Regional Research Laboratory, Eastern Utilization Research and Development Division, Agricultural Research Service, United States Department of Agriculture, Philadelphia 18, Pa.

[3]Note: The terms "absorbed" SO_2 and SO_2 "uptake" will denote in this paper the quantity of SO_2 present as indicated by the analytical method. It is recognized that some of the SO_2 taken up from the dipping solution reacts with the reducing substances in potatoes and some is oxidized by air.

In storage tests, in which the sulfited potatoes were analyzed at intervals, it was deemed better from the sampling standpoint to use French-fry slices instead of whole potatoes. A large quantity of sulfited 2 x ⅜ x ⅜-inch slices was put away and 100 grams (approximately 20 slices) removed when desired for the SO_2 determination.

Evaluation of Factors Influencing SO_2 Absorption

It has been found in previous work at this Laboratory and elsewhere that use of an acid such as citric acid in conjunction with the weakly acid salt $NaHSO_3$ provides more effective protection against discoloration of peeled potatoes than is furnished by $NaHSO_3$ alone. Under comparable conditions, more than twice as much SO_2 was absorbed from a $NaHSO_3$-citric acid dip as from one containing the same amount of $NaHSO_3$ but no citric acid. Acidification of $NaHSO_3$, either by addition of an acid or by the acidity of potato juice, liberates SO_2; the extent of sulfite treatment is usually measured in terms of SO_2 concentration present. While it is not unanimous in any sense, it is common for central peeling plants to employ a mixture of $NaHSO_3$ and citric acid. Hence, in these experiments equal amounts of $NaHSO_3$ and citric acid were always used in the dips.

Since the data are readily presented by graphs, it was decided to use this method of presentation instead of tabular style.

Concentration of dip. The concentrations of $NaHSO_3$ and citric acid were simultaneously varied from 0.125% to 1%. As shown in Fig. 1, the SO_2 uptake increased from about 100 to about 275 parts per million (ppm) with corresponding increase in concentration of dip. The peeled potatoes were dipped at room temperature and drained for 1 minute before starting the determination of SO_2.

Time of dip. The immersion time was varied from ½ to 4 minutes, again dipping the peeled potatoes at room temperature and draining for 1 minute before assaying for SO_2. At first the quantity of SO_2 uptake increased rapidly with time, as shown in Fig. 2. However, after about 1 minute's immersion, the rate of uptake decreased to a nearly linear relationship.

Temperature of dipping solution. It is generally accepted that it is good practice in central peeling plants to keep the potatoes cool during processing, to package them in protective bags that seal against entry of outside air, and to store the sulfited potatoes under refrigeration. From the standpoint of SO_2 absorption alone, however, the temperature of the dip seems to exert no great effect. Whole peeled potatoes were dipped for 2 minutes in 0.5% $NaHSO_3$-0.5% citric acid solution, drained 1 minute, and then assayed for amount of SO_2 absorbed. At 40° F., the average value for 2 experiments was 96 ppm SO_2; at 50°, the average value for 2 experiments was 89 ppm; at room temperature (about 75°), the average value for 3 experiments was 108 ppm SO_2 absorbed by the potatoes.

Experiments were made on variability of sampling, using 8 sulfited whole peeled potatoes. The SO_2 values obtained showed an average deviation of 7% from the mean. This is the magnitude of the difference

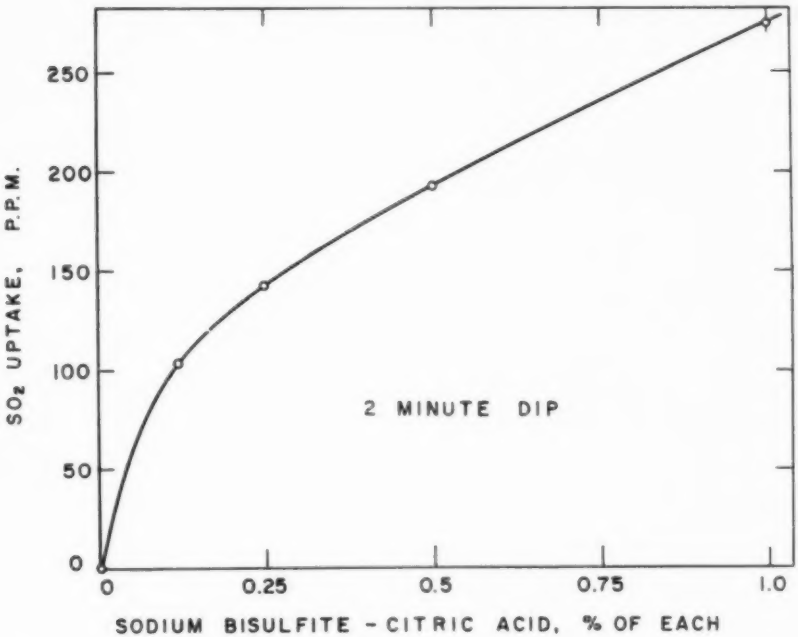

FIG. 1. Effect of concentrations of sodium bisulfite and citric acid on the sulfur dioxide uptake of dipped whole peeled potatoes.

found between the 40° and 50° values. Individual differences due to the tubers themselves can be ruled out only through some system such as quartering the tubers and using one-fourth of each of several tubers to compose the sample to be analyzed. In this study of factors influencing the SO_2 absorption, as these factors interest the processor of pre-peeled potatoes, we are concerned with larger rather than small differences.

Whole vs. sliced potato: Raw and cooked. A comparison was made of the SO_2 absorption obtained with whole potatoes as against French-fry slices 2 x ⅜ x ⅜-inches. In this it was found convenient to use potatoes that were peeled and trimmed to nearly spherical shape and to 107 grams weight. Since this lot of potatoes had a specific gravity of 1.07, the peeled spherical potato samples each had a volume of 100 ml. and a surface area of about 15 square inches. The surface areas of equal weights of whole potato and French-fry slices of the size used bore the ratio of about 1 : 6.

Whole peeled potatoes had an average uptake of 187 ppm SO_2 in this series of experiments. The French-fry slices had an average of 643 ppm SO_2 uptake. Boiling the whole potatoes for 25 minutes reduced the SO_2 content to an average of 75 ppm. French frying the slices reduced their SO_2 value to an average of 147 ppm.

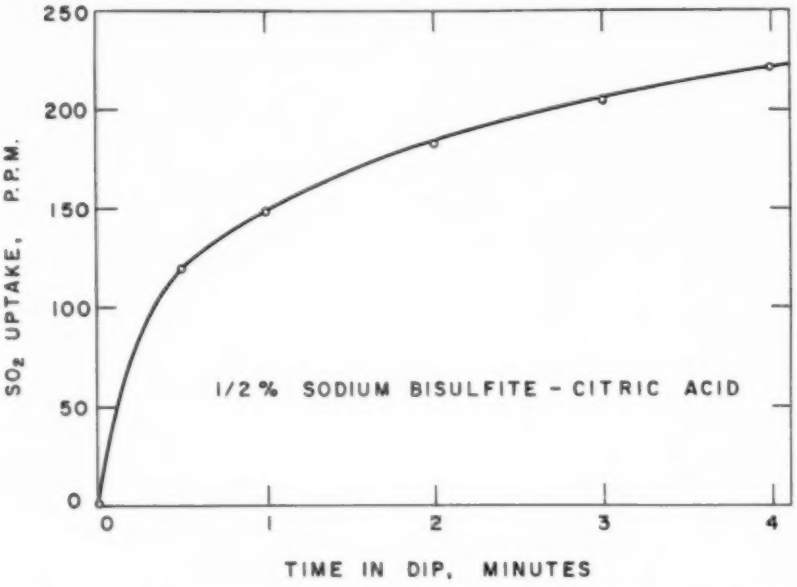

FIG. 2. Effect of immersion time on the sulfur dioxide uptake of dipped whole peeled potatoes.

SO_2 RETENTION IN STORAGE

French-fry slices were dipped in 0.5% $NaHSO_3$-0.5% citric acid solution for 2 minutes at room temperature, drained 1 minute, and then stored in a polyethylene bag in a refrigerator (37° F.). As Fig. 3 shows the SO_2 loss was more rapid at first and then assumed nearly a linear rate after about 2 days' storage. Although the SO_2 content of the potato slices at the end of the storage period (more than 15 days) was considerably lower than the original value, no measurable discoloration occurred at this low temperature with the protective packaging used.

SUMMARY AND CONCLUSIONS

A study was made of certain factors that influence the SO_2 uptake of sulfited pre-peeled potatoes. Use of a $NaHSO_3$-citric acid dip instead of $NaHSO_3$ alone greatly increased the absorption of SO_2. Upon increasing $NaHSO_3$ and citric acid in the dip simultaneously from 0.125% to 1%, SO_2 uptake regularly increased from average values of 104 to 274 ppm. With 0.5% each of $NaHSO_3$ and citric acid in the dip, SO_2 uptake increased regularly from 122 to 222 ppm as dipping time was increased from ½ minute to 4 minutes.. Temperature apparently has little effect on the quantity of SO_2 absorbed by peeled potatoes within the limits of 40° to 50° F., the range in which it is common to chill the dipping bath in a central peeling plant. At room temperature, i.e. about

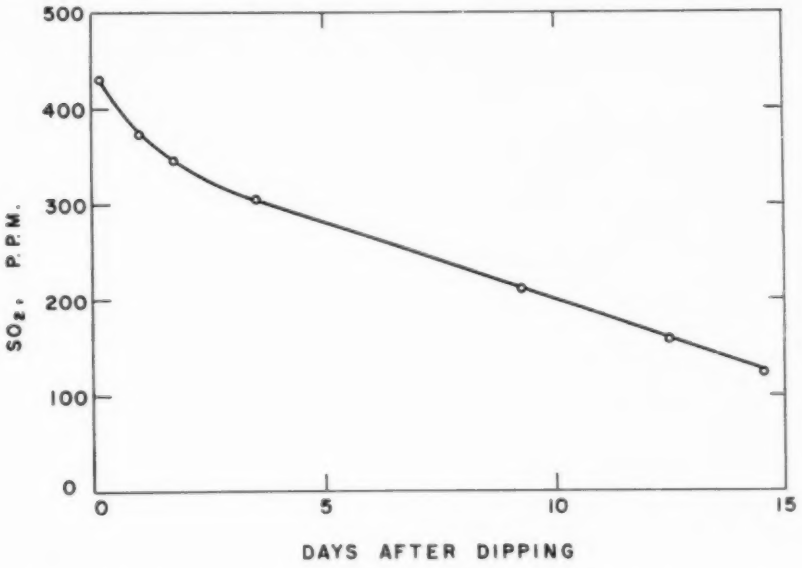

FIG. 3. Effect of 37° F. storage on the residual sulfur dioxide content of sulfited French-fry slices.

75°, somewhat more SO_2 was absorbed during a 2 minute immersion in 0.5% $NaHSO_3$-0.5% citric acid solution than under the same conditions of time and dip concentration in the lower temperature range.

Whole peeled potatoes absorbed less than one-third as much SO_2 as did French fry slices under comparable conditions. Boiling the whole potatoes reduced the SO_2 content to less than one-half the value in the raw state, and French frying the slices reduced the SO_2 content to less than one-fourth the former value.

During cold storage (37°F.), raw French-fry slices lost SO_2 fairly rapidly for the first few days and then at a slower, nearly constant rate such that an appreciable quantity of SO_2 remained even after 2 weeks.

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THE INTERRELATIONSHIPS OF POTATO DISCOLORATION, POLYPHENOL OXIDASE ACTIVITY, AND NITROGEN CONTENT OF POTATOES[1]

NELL I. MONDY AND BARBARA P. KLEIN[2]

Black spot of potatoes has been associated with the activity of the enzyme, polyphenol oxidase. Upon cell injury, such as mechanical bruising, the enzyme is thought to catalyze the oxidation of phenolic constituents to form the black pigment, melanin. The normal role of polyphenol oxidase in the metabolism of the tuber has not been clearly defined. Early workers associated this enzyme with terminal oxidation in the tuber (1, 2, 3, 4, 11). More recent work has shown that cytochrome ovidase activity in the tuber is sufficient to account for the normal respiration (8, 6, 17). Steward and Thompson (14) suggested that polyphenol oxidase functions as the terminal oxidase in potatoes that have been cut or otherwise injured, while cytochrome oxidase operates as the terminal oxidase in the intact tuber .The respiration of cut potato slices in oxygen was too high to be completely accounted for by cytochrome oxidase alone, and these workers postulated that some component of respiration which has a higher oxygen requirement than cytochrome oxidase was functioning at that time.

The Krebs oxidative pathway has been shown to occur in plants as well as in animal tissue. Gregory and Sen (7) suggested that some of the amino acids derived from protein breakdown may enter into the Krebs Cycle after they have been deaminated. Boswell (2) suggested that quinones formed by polyphenol oxidation may be reduced to polyphenols by amino acids. Ammonia released from amino acids is made available for protein synthesis. These findings indicate that there is some relationship between respiration and synthesis of protein.

Cell growth in the tuber is arrested at maturity but may undergo renewed growth when potato slices are placed in moist air. The nitrogen reserves, or the soluble nitrogen from which new protein is synthesized, are mobilized in cells in which synthesis occurs. Tubers contain a large store of non-protein nitrogenous material such as amino acids, amides and peptides from which protein can be synthesized. Steward *et al* (13), in studying the metabolism of potato discs, found a direct relationship between protein synthesis and respiration. These workers concluded that soluble nitrogen compounds, as well as proteins, are implicated in potato respiration.

In the present paper the interrelationships of potato macerate discoloration to nitrogen content, including both protein and non-protein fractions, and to polyphenol oxidase activity of tubers are presented.

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[1]Accepted for publication August 16, 1960.

[2]Associate Professor and Student respectively, Graduate School of Nutrition and Department of Food and Nutrition, New York State College of Home Economics and State Agricultural Experiment Station at Cornell University, Ithaca, New York.

Materials and Methods

Source of material

Two varieties of potatoes, Ontario which is susceptible to black spot and Pontiac which exhibits little black spot, were grown near Ithaca, New York in 1958. The potatoes were harvested eighteen weeks after planting, and were examined immediately and after one, two, three, four, five and six months of storage at 40°F.

Determination of enzyme activity. Four tubers were selected at random for the preparation of each extract. Two extracts of each variety were made at each storage period. The potatoes were washed, blotted dry and cut to give equal sampling of bud and stem ends. Samples were taken from the cortex area including the peel.

Fifty grams of tissue were blended with 50 ml of 0.05 M sodium barbiturate for one minute in the Waring Blender. The slurry was allowed to filter in the refrigerator through four layers of cheesecloth for three minutes, the filtrate centrifuged at 600 x g for three minutes, and the supernatant used as the source of the enzyme, polyphenol oxidase. All glassware used in the preparation of the extract was chilled in ice before and during the preparation.

Enzyme activity was measured manometrically by the method of Goddard and Holden (6) with some modifications. For the determination of polyphenol oxidase activity, 0.2 ml of the potato extract was added to one side arm and 0.8 ml of 6.82×10^{-2} M hydroquinone to the other side arm of the Warburg flask. The main compartment contained 1 ml of 0.5 M phosphate buffer at pH 7.1 and 0.2 ml of 4.55×10^{-3} M catechol. Water was added to bring the total volume in each flask to 3.2 ml. The side arm contents were added after a five-minute equilibration period at 30° C., stopcocks were closed and readings were taken every ten minutes over a one-hour period.

Determination of non-protein and total nitrogen. Four tubers were selected at random for each extract. Two extracts of each variety were made at each sampling period. The entire tuber was sampled.

a) Non-protein nitrogen determinations. Potatoes were chopped fine with a knife and a 50-g sample was blended with 95% ethanol to give an 80% ethanol extract of the tissue. The slurry was then filtered through Whatman No. 3 filter paper, the residue washed thoroughly seven times with 10 ml portions of 80% ethanol, and the washings combined with the original filtrate. The volume of the combined filtrates was then measured and 5-ml samples removed for nitrogen determination by the micro-Kjeldahl method. Triplicate determinations were made on each extract.

b) Total nitrogen determinations. Potatoes were ground in a food chopper and dried in a vacuum oven at 70°C. for 48 hours. Dried samples for the determination of total nitrogen were ground in a mortar. The micro-Kjeldahl method was used for nitrogen determination. Triplicate determination were made on each variety during each storage period. The per cent solids in the fresh potato was determined by drying 80-g samples of the diced potatoes in a vacuum oven at 70°C. for 48 hours. Duplicate determinations were made on each variety during each storage period.

Determination of color. Approximately 200 g of cortex tissue were ground in a food chopper and allowed to stand in air for twenty minutes. Tuber discoloration was determined using the Hunter Color Difference Meter. A standard grey color plate having values Rd 39.0, a –1.1, b –3.3, was employed for standardization of the readings. The ground potatoes were put into a specially designed glass container with an optical glass bottom and color reflectance, Rd, was measured.

Results and Discussion

Macerates of cortical tissue of Ontario potatoes discolored more than Pontiac potatoes throughout the study (Fig. 1). Varietal differences in discoloration were found to be significant at the 1% level. These findings are in agreement with earlier work in this laboratory (10). Massey (11) observed that Ontario potatoes had a higher black spot index than Pontiac potatoes. The Ontario variety was higher in polyphenol oxidase activity

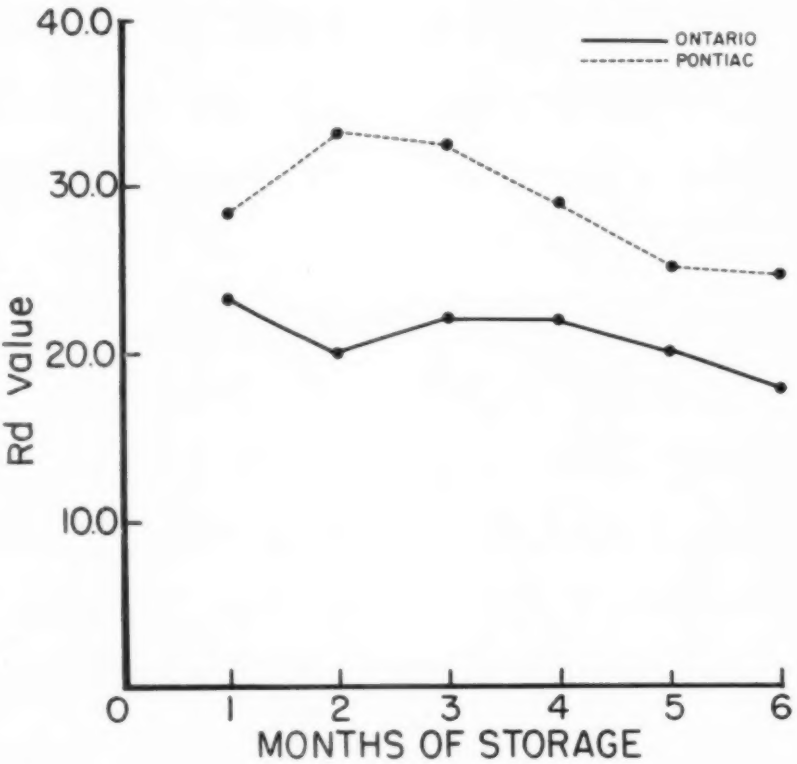

Fig. 1.—Discoloration of Pontiac and Ontario potatoes during storage at 40°F. Rd Values decrease as blackening increases.

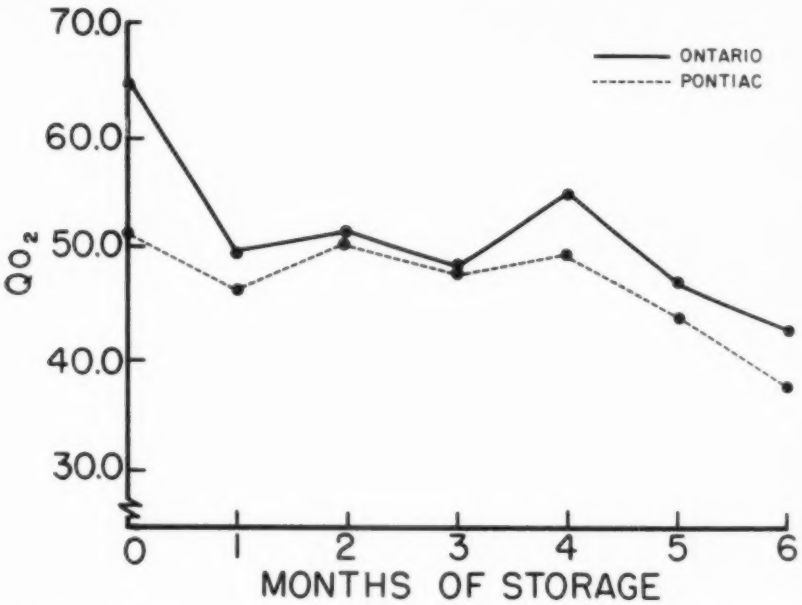

FIG. 2.—Polyphenol oxidase activity of Pontiac and Ontario potatoes during storage at 40°F.

(Q_{O_2}: microliters of oxygen uptake/hr./mg. dry weight of tissue. All values were corrected for endogenous respiration).

than the Pontiac variety as shown in Fig. 2. These differences were highly significant. There were no significant differences, however, in total nitrogen or non-protein nitrogen content in the two varieties (Fig. 3, 4).

Discoloration increased and polyphenol oxidase activity decreased in both varieties of potatoes during storage. The decrease in polyphenol oxidase activity was highly significant (Fig. 2). Ontario potatoes, the variety which is more susceptible to darkening, decreased 23% in polyphenol oxidase activity whereas Pontiac, the variety exhibiting less black spot, decreased only 9% during the first month of storage. The results of this study show a decrease in polyphenol oxidase activity with increased storage duration and are in agreement with those reported earlier in this laboratory (10). Previous work in this laboratory also showed that during storage the phenolic content of potatoes increased at the same time that polyphenol oxidase activity was decreasing. Phenolic compounds were found to accumulate more rapidly in Ontario than in Pontiac potatoes. The suggestion was made that increased phenolic concentration, rather than increased polyphenol oxidase activity, may account for some of the increase in potato darkening during storage.

In both varieties the increase in total nitrogen with increased storage duration was highly significant (Fig. 3). Other workers (12, 15, 16)

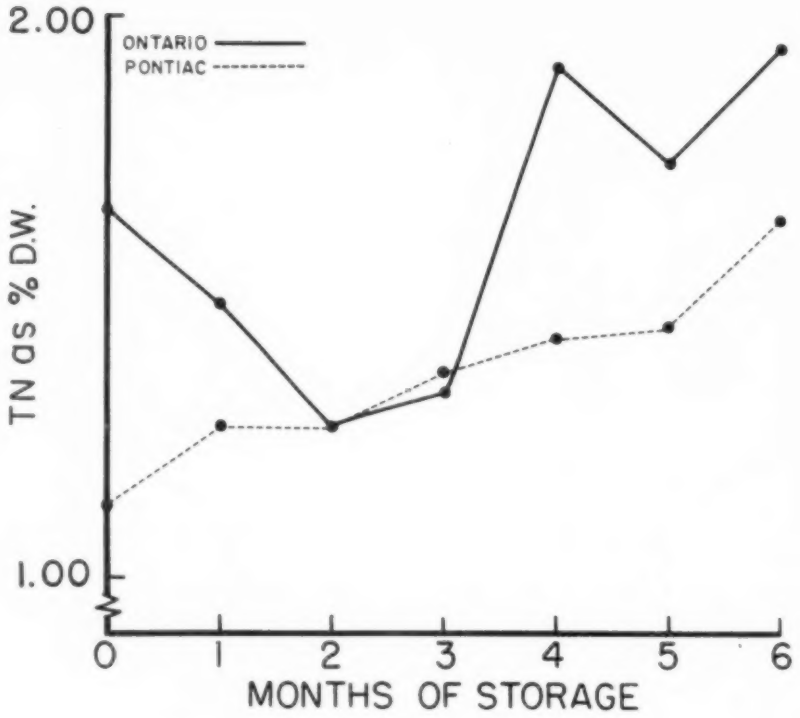

FIG. 3.—Total nitrogen content of Pontiac and Ontario potatoes during storage at 40°F. Values shown are total nitrogen as per cent of dry weight of tissue.

have also found an increase in total nitrogen with increased storage but they calculated total nitrogen on a fresh weight basis and made no allowance for loss of moisture during storage. In the present study, nitrogen was determined on the dry weight basis in order to eliminate errors due to water loss during storage. The increase in total nitrogen during storage may have been due to a decrease in other potato solids such as carbohydrates. It is assumed that potato carbohydrates would be used in potato respiration and thus bring about a decrease in the total solids content of the tuber. If this assumption is made, then the relative amount of nitrogen, as per cent of total solids, would be expected to increase.

The non-protein fraction in both varieties decreased more than 50% during six months of storage while the total nitrogen content increased. Since protein nitrogen is the difference between total nitrogen and non-protein nitrogen, one may conclude that protein is synthesized in the potato during storage (Fig. 4). Shallenberger (12) also observed a decrease in non-protein nitrogen during storage. Contrufo and Levitt (5) found an increase in the protein fraction of tubers from the time of harvest until the first sign of sprouting.

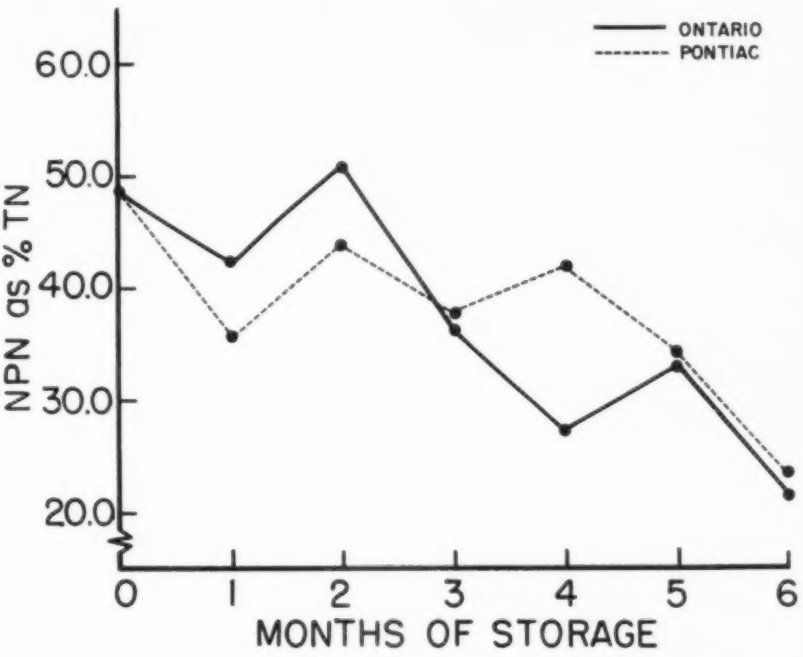

FIG. 4.—Non-protein nitrogen content of Pontiac and Ontario potatoes during storage at 40°F. Values shown are non-protein nitrogen as per cent of total nitrogen.

In the present study the proportions of non-protein to protein nitrogen were approximately the same in both potato varieties for the first three months of storage. During the last three months of the six-month storage period, however, the non-protein fraction decreased more rapidly in Ontario than in Pontiac potatoes indicating that more protein synthesis occurred in the Ontario variety.

Interrelationships. Potato discoloration was negatively correlated with polyphenol oxidase activity. The color number, as expressed by Rd readings, showed a positive correlation with polyphenol oxidase activity, but one should remember that the Rd reading decreases with increased potato darkening. The pooled partial correlation coefficients with 24 degrees of freedom was 0.520 and was highly significant. Although the Ontario was higher than the Pontiac variety in polyphenol oxidase activity throughout the study, Ontario potatoes showed the greater decrease in polyphenol oxidase activity during storage. Perhaps the amount of polyphenol oxidase activity in the potato relative to the amount found at the time of harvest is an important factor in potato discoloration. If the amount of polyphenol oxidase activity is originally high and drops suddenly during storage, discoloration will occur more readily than if the potatoes were originally low in polyphenol oxidase activity.

Although greater darkening occurred in Ontario potatoes, the variety which showed a greater decrease in non-protein nitrogen during storage, no significant correlation of potato darkening with non-protein nitrogen content of potatoes was found. The increase in total nitrogen was not consistent throughout the six-month storage period for Ontario potatoes. A decrease in total nitrogen during the first few months was followed by an increase during the last 3 months of storage. Changes in total nitrogen were not correlated with the tendency of potato macerates to darken. Perhaps there are other factors, in addition to those observed in this study, that are affecting potato discoloration.

Summary

The relationship of tuber macerate discoloration to polyphenol oxidase activity and nitrogen content of potatoes was studied. Two varieties of potatoes, Ontario which is susceptible to pre-cooking discoloration and Pontiac which exhibits little discoloration were studied.

Ontario potatoes discolored more than Pontiac potatoes and were higher in polyphenol oxidase activity. Upon storage, however, the greater percentage loss in polyphenol oxidase activity occurred in Ontario potatoes. The tendency of the tuber to discolor was significantly correlated with the loss of polyphenol oxidase activity. More discoloration occurred in the Ontario variety which also showed the greater loss in polyphenol oxidase activity.

Total nitrogen content of both varieties increased with storage duration. The non-protein nitrogen decreased during storage, indicating that protein synthesis occurred. More protein synthesis occurred in Ontario than in Pontiac potatoes. Discoloration of potato macerates was not correlated with protein synthesis.

Acknowledgment

The authors wish to acknowledge the assistance of Dr. Ora Smith, Richard Sawyer, Mr. George Collins, and Mr. Eric Kissmeyer-Nielsen, Department of Vegetable Crops, Cornell University for the arrangements made in growing and harvesting the potatoes. Grateful acknowledgment is also made to Dr. John Skory for his guidance and assistance in the statistical analyses.

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EFFICIENCY IN THE USE OF WATER BY POTATOES[1]

R. A. STRUCHTEMEYER[2]

Maine as well as many other experiment stations has been studying for many years, the use of supplementary irrigation on potatoes. A review of past results shows that there has been some disagreement as to the influence of time of irrigation and soil moisture tension on potato yields.

Bradley and Pratt (2) found that the highest yields of potatoes were obtained if plots were watered prior to the soil moisture dropping to a level of 50% of field capacity. Jacobs et al (5) found that potatoes should be irrigated when soil water reaches 50 to 60% of field capacity. He also noted that over irrigation would reduce yields.

At New Jersey, Blake et al (1) obtained an increase in yield from irrigation but found no difference in yield as a result of allowing soil moisture levels to be reduced to 35, 50 or 67% of field capacity. Fulton and Murwin (4) studied the effect of soil moisture depletion to 25, 50 and 75% of field capacity. He obtained an increase in yield for 50% over 25 but no further increase for 75%.

Fulton (3) concluded that timing of irrigation was very important. Taylor and Rognerud (7) found that irrigation before and during tuber set gave an increase in number of tubers formed. Along the same line, Larsen (6) noted that water was very important to the potato plant up to the time of blossoming.

Based on these reports and field observations, a series of greenhouse trials were started in 1957 at the University of Maine. The two variables considered were time of irrigation and soil moisture tensions.

MATERIALS AND METHODS

The potato variety used in this series of studies was the Katahdin. Seedpieces of a uniform size were planted in 2-gallon crocks about three inches below the surface of the soil. Soil used was a fine sandy loam of medium fertility with a pH of 5. The soil was fertilized with 8-12-12-2 fertilizer at a rate equivalent to 2,000 pounds per acre. Lime was added at the rate of 2,500 pounds per acre. The lime was mixed thoroughly with the soil first and then the fertilizer was mixed with it.

Gypsum moisture blocks were placed in each pot, two inches from the bottom. When moisture levels of 70, 50, 30 and 15% available water were reached measured amounts of water were added to the respective pots to bring them back to field capacity. The potato plants in all of the trials were allowed to grow 110 days.

All of the pots were placed in a water bath which provided a soil temperature range varying from about 54° F. during the night to about 65° F. during the day. The air temperature in the greenhouse was fairly constant at 68° F. This procedure was used to encourage the plants to produce a greater quantity of tubers than they would if the soil remained the same temperature as the air in the greenhouse. Lights were available over the plants so that it was possible to vary the day length as

[1]Accepted for publication June 3, 1960.

[2]Head, Department of Agronomy, Maine Agricultural Experiment Station, Orono, Me.

desired. The treatments were set up in randomized blocks and were replicated four times.

Results

Table 1 shows that as the per cent of available moisture decreases the yield of tubers decreases. The data presented are averages of four replicates.

Table 1.—*Influence of different soil moisture tensions expressed as per cent available moisture on yield of potatoes.*

Per cent available water*	Yield of potatoes in grams per crock		
	1957	1958	1959
70	224	94	267
50	165	70	169
30	142	56	45
15	77	34	1
L.S.D. 5%	59	39	62

*Measured by gypsum blocks.

Table 2 shows the results obtained when the per cent of available moisture was held at a given level for 55 days and then at another level for an additional 55 days.

Table 2.—*Influence of time of irrigation on potato yields.*

Per cent available water		Yield of potatoes in grams per crock	
Early*	Late*	1958	1959
15	70	11.7	6.3
30	70	83.3	79.0
50	70	111.7	95.2
70	15	0	19.2
70	30	19.2	68.0
70	50	56.2	142.2
L.S.D. 5%		39	43.

*First figures indicate moisture levels maintained for first 55 days after planting. Second figures give moisture levels for last 55 days of growing season.

In general the trend is the same as in the previous set of data. It shows that a shortage of soil moisture either early or late in growth cycle of the potato reduces yield. Generally speaking the effect of a shortage of soil moisture is most pronounced when it occurs in the last half of the growing season.

One of the surprising things indicated by the data was that the number of tubers formed was not consistent in its relation to per cent of available soil moisture as had been anticipated. When there were signi-

ficant differences in the data for the number of tubers formed, it closely paralleled the trend in the yield data.

Dry matter weights of the tops also closely followed the trend of tuber yields.

No outward differences in the shape or appearance of the tubers produced at the various soil moisture tensions was noticed.

Conclusions

1. As the per cent of available soil moisture decreases the potato yields decrease.
2. Shortage of soil moisture in the last half of the growing season tended to reduce yield more than a shortage during the first half of the growing season.

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NEWS AND REVIEWS

RECENT RESEARCH AND DEVELOPMENT IN POTATO FLOUR AND POTATO STARCH[1]

R. H. TREADWAY[2]

Potato flour and potato starch are sometimes looked upon mistakenly as being the same thing. In reality, flour is a cooked dried product containing the entire potato composition except the peel. Starch is a high purity product substantially free from all other constituents of the potato.

POTATO FLOUR

The historical background, manufacturing methods, chemical composition, and uses of potato flour were discussed in recent articles (4, 5). Therefore, this brief account will include only such portions of the cited material as believed necessary for our present purpose.

Potato flour seems to have been the first processed potato food product to reach commercial production. It was produced in the U. S. during World War I as a substitute for wheat flour. In producing flour, potatoes are peeled, cooked, dried on a drum drier, and then ground to a meal or powder.

More than 90% of the potato flour is used in the baking industry. From 2 to 6% potato flour (based on the weight of wheat flour) is used in potato bread. Addition of potato flour improves the fermentation of the dough, leading to better loaf volume and flavor. Potato crackers have recently become another important outlet for potato flour. These crackers contain 15-20% potato flour and are thin and crisp, with texture resembling potato chips. They have a tasty flavor and provide an excellent snack as such or with cheese dips, refreshing beverages and nourishing soups. Potato flour is also used in cookies, cakes, and pastries, and in prepared mixes such as those for doughnuts. Potato flour is used to a lesser extent as a "breading" agent for meats and other foodstuffs, as a thickening agent in soups and sauces, as an extender in meat loaf, and in scrambled eggs.

For many years, the demand for potato flour was stabilized at such a level as to require about 1 million hundredweights of potatoes annually as raw material. Flour production has been on the increase, however, during the past 7 years. The National Potato Council estimates that the following amounts of potatoes (millions of hundredweights) were consumed in flour production from recent crops: 1953, 0.93; 1955, 1.74; 1958, 1.86; 1959, 2.22.

Potato flour is produced in Southeastern Idaho and in the Red River Valley. The raw material is mainly culls remaining after U. S. No. 1 and

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[2]Eastern Regional Research Laboratory, Eastern Utilization Research and Development Division, Agricultural Research Service, United States Department of Agriculture, Philadelphia, Pa.

2 potatoes have been removed. The potatoes must be in sound condition and trimmed to remove decayed tissue.

Developments. Continuing research and development are being conducted by the industry on improvement of the process, improvement of the quality of the product, and extension of the uses for potato flour. Steam peeling is the preferred method at present in flour plants rather than lye peeling. Recently Adams, Hickey, and Willard (1) found that dipping the potatoes in hot lye solution followed by a short exposure to superheated steam gave more efficient and economical peeling than either steam or lye alone.

Willard and Englar (6) have pointed out that water absorption in a wheat flour-potato flour mixture increases in direct proportion to the amount of potato flour used in the dough. By closer control of certain steps in the manufacture of potato flour, it is possible to make flour that absorbs the maximum amount of water and also to obtain uniformity in water absorption. Presumably, the condition of the starch in the flour is the principal governing factor.

The increased demand for potato flour is generally credited to the development of potato crackers and to improvment in the quality of the flour for breadmaking. While the potato flour industry is faced with problems, it is to be hoped that the use of this product will continue to grow.

Potato Starch

The historical development of the American potato starch industry, statistics of production, methods of production,, and uses for potato starch and its derivatives are discussed in recent publications (2, 3). Hence, this summary will survey this previously-covered material only to the extent necessary to provide background for discussing the most recent research and development.

The first potato starch plant in the U. S. was established at Antrim, New Hampshire, in 1831. Potato starch production expanded during the middle of the nineteenth century and then lost its prime position to cornstarch, which became cheaper to make. However, an upsurge in potato starch production occurred about 1940, and there are today more than 20 plants in Maine and more than a dozen plants in Idaho and other Western locations. Productive capacity is about equally divided between the Maine and Western plants.

Potato starch plants operate from about October 1 to about June 1 of the following year, to give a total of approximately 200 operating days. The plant operators use cull and surplus potatoes, for which they ordinarilly pay about 35¢ per hundredweight. Rarely, if ever, is the supply of raw material sufficient and evenly distributed enough to permit capacity production in all plants during the entire season. A total production throughout the industry of 150 million pounds of starch per year is considered a good season. This represents the yield from grinding perhaps 15 million hundredweights of potatoes.

In producing starch, the potatoes are washed and disintegrated to a finely-divided mass. The diluted mass is then screened to separate the extracted pulp from the "starch milk" containing suspended starch and the

solubles dissolved in the processing water. The starch is further washed by passing it through centrifugals, and it is then dewatered and dried.

Several years ago it was estimated that Maine potato starch was used in its various outlets in approximately the following proportions, expressed in percentages: paper, 60; textiles, 30; food, adhesives, and miscellaneous, 10. In the absence of any utilization estimate of the output of the Western starch factories, it may be assumed that the overall use pattern is in the same range as that for Maine. In the paper industry, potato starch is used for sizing and coating. Warp sizing, thread finishing, and cloth finishing are the textile applications. Applications in the food industry are in baked goods and confections. There are manifold applications of potato starch and dextrin as adhesives and in miscellaneous uses.

New plant. While several new potato starch plants have been established in the past few years, one being built at Houlton, Maine, is attracting most attention at present. According to press reports, this plant will cost $1,720,000 and will include facilities for starch manufacture, conversion of starch to modifications, production of starch derivatives, and waste recovery and processing to byproducts. The plant will have 70,000 square feet of floor area and capacity for grinding about 8,250 hundredweights daily. The capacity to convert starch to products such as dextrin (by roasting), thin-boiling starch (by acid treatment), and oxidized starch (sodium hypochlorite treatment) is said to total 60,000 pounds daily. Converted starches are used instead of unmodified starch when it is desired to have a high concentration of starch present without encountering excessive paste consistency. Some modifications result in greater tackiness and adhesive strength. Others may result in a paste that resists setting to a gel when cooled. Still other modifications may result in increased clarity of the paste and dried film.

Modifications and derivatives. The native starch molecule is made up of many glucose units joined together. In producing modifications, there are breaks in the chains of glucose units comprising the giant starch molecule. The starch molecule is thus reduced in weight or is "degraded".

In the formation of starch derivatives, substitution of a chemical group occurs at one or more of the three hydroxyl groups in a glucose unit. The most important potato starch derivative at present is hydroxyethyl starch, made by reaction of ethylene oxide on alkali starch. The commercial hydroxyethyl tarch is prepared by low degree substitution, that is, only a small fraction of the hydroxyl groups are involved in the reaction. hydroxyethyl starch is prepared by low degree substitution, that is, only to an insoluble film. Thus it is ideally adapted for sizing synthetics and other new types of textiles, where ordinary starch lost out because of poor performance. Spun rayon, spun nylon, polyester-cellulose, and cellulose triacetate warps can be sized very satisfactorily with hydroxyethyl starch properly formulated with other ingredients. Hydroxyethyl starch can also be blended with melamine-formaldehyde and urea-formaldehyde resins for making water-resistant finishes for textiles.

Potato starch ethers, such as hydroxyethyl starch, have been imported from Holland in recent years to the extent of several million pounds annually. The necessary research and development has been done

by the American industry to permit commercial production of these derivatives in the U. S., as is now planned.

Food developments. Potato starch also has desirable properties for use in instant desserts based on pregelatinized starch. In preparing pregelatinized starch, starch is slurried in water and then heated above the gelatinization temperature to provide a heavy dough. The dough is then dried on a drum drier, the dried film is scraped off by a doctor blade, and the film is ground to a powder. In formulating an instant pudding mix, the following ingredients may be included: pregelatinized starch, sugar, flavor, color, and sodium phosphates. When cold milk is added to the dry mix, the pregelatinized starch absorbs much of the water in the milk. The phosphates coagulate the milk protein. The combined effect, attained in a few minutes, is that a soft gel is formed. The gel is sufficiently firm to retain a molded shape.

Pregelatinized starch is also good for formulating quick pie fillings, frostings, meringues, icings, instant sauces and dressings, and batters for use in the deep-fat frying of fish, meat, and poultry.

Byproducts. Recent research at the Eastern Regional Research Laboratory on methods of separating and recovering nitrogenous compounds from potato starch processing water may be commercialized in the not too distant future. While the extracted pulp from starch factories is dried to provide a high-carbohydrate feed component, no use has been made to date of the substances in the processing water. Passage of the dilute, deproteinized processing water through an ion exchange column packed with Dowex 50 resin (H^+ form) results in adsorption of the amino compounds while other constituents pass through. The absorbed amino compounds are then removed by passing a limited volume of 2 Normal ammonium hydroxide through the column. The potato amino compounds can thus be obtained in much higher concentrations than they occurred in the original liquor. The concentrated fractions are then mixed and dried to a powder. This dried powder shows promise as a food flavoring agent.

The potato processing water has also been concentrated to 50-60% total solids to give a stable concentrate rich in nitrogenous compounds, sugars, organic acids, and inorganic compounds. This concentrate has been found to be valuable as a nutrient for industrial fermentations.

Conclusions

From the above discussion of potato flour and potato starch, we see that advances are being made as the results of research and development. We expect the demand for these two products from potatoes to continue to grow.

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BOOK REVIEW

RADIATION TECHNOLOGY IN FOOD, AGRICULTURE, AND BIOLOGY. N. W. Desrosier and Henry M. Rosenstock. Avi Publishing Co., Inc. Westport, Conn. 1960.

For one who is versed in the principles of radiation and is primarily interested in bringing himself up-to-date on the applications of radiation in biology, this book should be just what he needs. Notwithstanding the inordinately high degree of optimism displayed in successive presentations of different aspects of biological material, especially foods, these presentations are excellent. Deserving special mention are the chapters on radiation effects on single cells, radiation effects on animals, and radiation effects on plants. In the last named is a section on "Interruption of Plant Growth with Ionizing Radiations" which embodies an exposition several pages in length on the control of sprouting in potatoes in storage by means of radiation. This type of application, requiring dosage of radiation below the range of magnitude which, in most instances, results in objectionable deterioration of quality of food, promises to become one of the most useful types of application of radiation to food improvement.

In this book are discussed practically all industrial applications of radiation in the biological field which have been visualized as potentially possible without going broadly into a discussion of the factors which constitute present indications that many of these applications show limited promise of success. At the same time, the reader cannot help being impressed with the vastness of the real prospects for useful application of radiation to advance science and technology in the realms of agricultural produciton, food distribution, and, in fact, the over-all sphere of biology. Areas of especially great promise appear to be those of treating materials not destined for human or animal consumption for the purpose either of testing these materials or of converting them into more useful forms and of diagnosis of disease.

The reader is made vividly aware of the full realization on the part of law-enforcement agencies and of scientific and technological personnel working in the field of radiation that extreme measures are necessary to protect human and animal life against exposure to radio-activity and against consumption of substances which might be rendered harmful by radiation.

Numorous definitions and other expressions pertaining to important specific aspects of properties of radiation are so worded as to be misleading to one who is just experiencing his initiation into the subject being discussed. Collectively, these things indicate that the purpose of the authors

was primarily to instruct the reader in the facts regarding discoveries and experience bearing on the applications of radiation in the sphere of biology and to give a brief review of the fundamentals of radiation technology for the reader who has already attained a state of advanced sophistication in the subject. These objectives must be regarded as adequately attained.

As a reference book on radiation, this book has limited value because of the restricted scope of its index.

Bibliography is extensive for each chapter..

C. OLIN BALL, *Chairman, Department of Food Science, Rutgers University.*

GALLEGLY WINS AWARD

Dr. M. E. Gallegly, professor and plant pathologist at West Virginia University, Morgantown, West Virginia received high honors at the recent meeting of the American Association for the Advancement of Science in New York. He is shown at left receiving the AAAS-Campbell Soup Company medallion, which carries with it a $1500 cash award, from Dr. Francis C. Clark, University of Maryland. Others are Dr. Chauncey D. Leoke, 2nd from left, president of AAAS and Dr. S. G. Younkin, Director of Agricultural Research for Campbell Soup.

The award was given to Dr. Gallegly for his work on the late blight of tomato and the relationship of this aspect of the disease to that found in potatoes and in the wild species of these two food crops. The award was granted by the Campbell Soup Co. for "an outstanding single research contribution, of either fundamental or practical significance, relative to the production of vegetables — for processing purposes." Resistance to late blight was unknown when Dr. Gallegly began his work. In screening approximately a thousand plant introduction tomato accessions, resistance was found in a number of small-fruited lines which were used in the breeding program. As his work progressed a single dominant gene for resistance was identified in tomato as well as a high degree of multigenic resistance. The types of resistance found paralleled the types in potato except for the number of dominant genes.

Dr. Gallegly is a member of The Potato Association of America and has presented papers on late blight at our meetings. We wish to congratulate Dr. Gallegly for his fine work and for this recognition by one of the nation's outstanding scientific associations and foremost vegetable processing company.

ACREAGE MARKETING GUIDES: WHAT THEY MEAN TO POTATO GROWERS

How Many Potatoes Should You Produce?

Potato growers face this question every year — and their profits often depend on their answer. When potato production is balanced with requirements, growers get good prices and stable markets. When production outstrips demand, growers usually suffer.

Markets Unstable in Past

A little too much production means sharply lower prices for all producers. Typically, if production goes up 1%, prices drop 5%. The reverse, of course, is also true.

Too often both potato supplies and potato prices have jumped up and down from year to year. For an actual example, look at the years from 1951 to 1960. Fall potato production varied an average of only 9% from year to year—but that caused prices to swing an average of 58%.

In the long run, this up-and-down pattern works against the potato producer.

Potato Growers Can Stabilize Market

Potato growers, as a group, can do something about this — by working together to match their production to the market for potatoes. The demand for potatoes is pretty stable from year to year. Changes in the supply make the price erratic. If potato growers produce just the right volume of potatoes to supply their market, they get the best return from their crop.

If the potato industry is to do this, each grower must know how he fits into the over-all picture — what he must do to match production and demand.

Acreage Guides Take Out Guesswork

The Acreage-Marketing guides are put out by the U. S. Department of Agriculture to help potato growers take the "guesswork" out of planning their production. Each guide is basically a market analysis. In fact, the guides are more what the *market* says than what USDA says. They are the best available estimates of how many potatoes growers can sell at a profit — and how many acres they'll need to grow them.

The guides are prepared by USDA specialists who live with the potato situation throughout the year. They study the ups and downs of the market, check production and market opportunities. They have the complete reports on how many potatoes were sold in past years — where they were sold, how much they sold for. They've studied shifts in the industry and shifts in how potatoes are used. All of this is wrapped up in the acreage guides.

Guides Available to All Growers

The guides for each potato season are issued in a booklet available from your local Extension office or from the U. S. Department of Agriculture. Each booklet contains the market analysis and the recommended acreage adjustments for individual growers in each producing section.

The guides for the winter potato crop are published in August, for the spring crop in October and for the summer and fall crops in early February. The guides are strictly voluntary. But they provide an answer to the big question — how many potatoes should be produced. The rest is up to the growers and if each grower does his part, the result will mean better returns to all growers. Be sure and get a copy for your own use.

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